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CIRCUIT ARRANGEMENT FOR THE INDUCTIVE TRANSMISSION OF ELECTRIC ENERGY

The invention pertains to a circuit arrangement for the inductive transmission of electric energy, for example, for supplying a small electrical appliance with power and/or for inductively charging a battery.

DE 38 42 465 A1 discloses a switching controller for a d.c.-d.c. conversion which comprises an electronic switch and a series-resonant circuit instead of an inductor. The switching controller oscillates with the resonant frequency of the series-resonant circuit and therefore has a particularly high efficiency if the electronic switch switches in the zero crossings of the current. The electronic switch is realized with two complimentary switching transistors that are controlled in antiphase. The control of the switching transistors is realized with a feedback circuit and input stages for the switching transistors that are not described in detail.

DE 40 15 455 A1 discloses a control circuit for an inverted rectifier that comprises a push-pull output stage with complementary transistors. The control of the transistors is realized with two electrically coupled control signals of mutually shifted potential. The connecting and disconnecting control signal edges are shifted by means of a delay circuit such that the initially switched-on transistor is switched off before the still switched-off transistor is switched on. This means that this control circuit is relatively complex.

The present invention is based on the objective of disclosing a circuit arrangement for the inductive transmission of electric energy that makes it possible to achieve a high efficiency with a low circuit expenditure.

According to the invention, this objective is attained with a circuit arrangement with the following characteristics: an oscillating circuit, a push-pull circuit with complimentary switching transistors that are adapted to excite the oscillating circuit, a control circuit for the complimentary switching transistors that preferably also contains complimentary control transistors, and a frequency generator, the output signal of which can be fed to the control transistors.

With respect to a high efficiency of the circuit arrangement, it is advantageous to at least approximately tune the oscillating circuit to the frequency of the frequency generator. It is also advantageous with respect to a reduction of the power loss in the switching transistors if these transistors can be controlled with a square-wave signal, i.e., if the frequency generator delivers a square-wave output signal. In addition, the initially switched-on switching transistor should already be switched off before the still switched-off switching transistor is switched on in order to prevent the voltage source from being quasi short-circuited by the two switching transistors that are simultaneously switched on. This is the reason why the control circuit for the switching transistors comprises a resistor and two capacitors in addition to the complimentary control transistors in one preferred embodiment of the circuit arrangement according to the invention. The resistor connects the control terminals of the switching transistors, the first capacitor is arranged parallel to the main current path of the first control transistor, and the second capacitor is arranged parallel to the main current path of the second control transistor, wherein the first capacitor is connected to the first end of the resistor and the second capacitor is connected to the second end of the resistor. Due to these measures, one switching transistor is switched off faster than the other switching transistor is switched on.

The oscillating circuit has an inductor and a capacitor. The inductor can be realized, for example, in the form of a coil that may form the primary coil of a transformer. A secondary coil can deliver electric energy in this case. The circuit arrangement according to the invention can be used, for example, for supplying electric energy to a small electrical appliance that contains the secondary coil, preferably electric toothbrushes or electric razors that may also contain a battery.

The invention is described below with reference to one embodiment of a circuit arrangement according to the invention for the inductive transmission of electric energy that is illustrated in the only figure. Other embodiments are discussed in the following description.

The circuit arrangement according to the invention that is illustrated in the figure comprises two switching transistors in the form of complimentary field effect transistors T2, T4, the drain terminals of which are connected to one another and to one end of a resonant circuit consisting of an inductor Lpr and a capacitor Cpr. The other end of the resonant circuit and the source terminal of the n-channel field effect transistor T4 are connected to ground. The source terminal of the p-channel field effect transistor T2 is connected to the plus pole of a voltage source U1. The minus pole of the voltage source U1 is connected to ground. The circuit arrangement comprises two additional control transistors in the form of complimentary field effect transistors T1, T3, the gate terminals of which are directly connected to the input of a frequency generator F that generates an output signal referred to ground. The gate terminals of the switching transistors T2, T4 are connected by means of a resistor R1. One end of the resistor R1 is connected to the drain terminal of the p-channel field effect transistor T1, as well as to the plus pole of the voltage source U1 by means of the first capacitor C1. The other end of the resistor R1 is connected to the drain terminal of the n-channel field effect transistor T3, as well as to ground by means of a second capacitor C2. The source terminal of the p-channel field effect transistor T1 is connected to the plus pole of the voltage source U1. The minus pole of the voltage source U1 is connected to the source terminal of the n-channel field effect transistor T3.

In another embodiment of a circuit arrangement according to the invention, the complimentary field effect transistors T2, T4 and/or the complementary field effect transistors T1, T2 are replaced with complimentary bipolar transistors.

In another embodiment of a circuit arrangement according to the invention, the polarities of the voltage source and the transistors are reversed.

Other variations of the above-described embodiments of a circuit arrangement according to the invention lack the capacitors C1 and C2, i.e., the function of these capacitors is respectively fulfilled by the gate-source capacitance and the base-emitter capacitance of the transistors T2, T4.

The function of the circuit arrangement illustrated in the figure is briefly described below. The switching transistors T2, T4 are wired in the from of a push-pull stage and alternately connect the resonant circuit to the operating voltage and to ground, wherein the push-pull stage is controlled with square-wave signals by the control transistors T1, T3. The capacitors C1, C2 and the resistor R1 are provided in order to prevent that the switching transistors T2, T4 simultaneously carry a high drain current. For example, if the output signal of the frequency generator F is positive, i.e., if it approximately assumes the operating voltage, the control transistor T3 is conductive and the control transistor T1 is non-conductive. Consequently, the switching transistor T2 is conductive and the switching transistor T4 is non-conductive. When the output signal of the frequency generator F changes to ground, i.e., the reference potential, the control transistor T1 and the switching transistor T4 become conductive while the control transistor T3 and the switching transistor T2 become non-conductive. This causes the gate-source voltage of the switching transistor T2 to drop with a time constant R′C′, wherein R′ refers to the track resistance of the now conductive control transistor T1 and C′ refers to the sum of the capacitance of the capacitor C1 and the input capacitance of the switching transistor T2. The gate-source voltage of the switching transistor T4 simultaneously increases with a time constant R′′C′′, wherein R′′ refers to the sum of the resistance of the resistor R1 and the track resistance of the now conductive control transistor T1 and C′′ refers to the sum of the capacitance of the capacitor C2 and the input capacitance of the switching transistor T4. Assuming that C′ is practically equal to C′′, R′C′ is much shorter than R′′C′′ because the resistance R′ is much lower than the resistance R′′, i.e. the switching transistor T2 is switched off faster than the switching transistor T4 is switched on. If the capacitors C1, C2, the input capacitances of the switching transistors T2, T4 and the track resistances of the control transistors T1, T3 are approximately equal, one switching transistor consequently is always switched off faster than the other switching transistor is switched on. The time delay between switching on and switching off can be adapted to the switching and delay times of the switching transistors T2, T4 by choosing the ratings of the capacitors C1, C2 and of the resistor R1 accordingly.